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Population Growth of Tomato Leaf Miner Moth (Tuta Absoluta) within Loitokitok Kajiado County-Kenya

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Abstract
The main purpose of the study was to assess the population growth of the invasive pest Tuta absoluta within Loitokitok district, Kajiado County in Kenya. The study used primary data that was collected from the experiment. The experiment was conducted to assess the population growth of Tuta absoluta. The study showed a variation on the number of Tuta absoluta collected from the protected and unprotected plants when Chlorantraniliprole was used to protect the plants from infestation. The results showed that the total mean number of larvae collected weekly during the period ranged from 1.3±0.6 to 20.8±3.4 in the protected plants and from 4.3±0.6 to 51.7±2.1 in the unprotected plants.

Keywords: *Tuta absoluta*, Tomato, Population growth, Loitokitok Kajiado County-Kenya.
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1.0 Introduction

The horticultural sector directly and indirectly employs over six million Kenyans thereby reducing the poverty levels within the country. According to Ongeri (2014), the horticulture sector employs close to 2.5 million people both in the formal and informal horticultural setups. Horticulture helps in achieving the national development agenda, which has been anchored in the Kenya Vision 2030. The sector consists of fruits, vegetables, nuts, flowers, aromatic and medicinal plants. Nutritionally, fruits are very vital in daily supply of minerals and vitamins (Preedy, 2008).

The livelihood of most of the Kenyan rural population depend majorly on the agricultural sector, which is crucial to food security and poverty reduction. The horticultural sector has six subsectors including, industrial crops, livestock, food crops, horticulture, forestry and fisheries. The horticultural sector has grown tremendously becoming one of the major employer, foreign exchange earner, and ensures food security within the country.

Although tomato is produced in almost every part of Kenya, areas with high rainfall are not good because tomatoes are highly susceptible to fungal diseases such as, late and early blight. The major production areas in Kenya are Loitokitok, Meru, Embu, Nyeri, Nakuru, Mwea, Kisii, Muranga, Busia, Bungoma, Trans Nzoia, Kakamega, Taita Taveta, Kilifi, Garisa, and Kisumu among others (HCDA, 2017).

Tomato production and marketing is constrained by abiotic and biotic factors, including the fruits perishable nature, pest and disease infestation (Suzuki *et al*., 2014). Other factors affecting its commercialization are high input cost, short storage life, seasonal gluts, poor market infrastructure, and poor technique in handling post-harvest (James *et al.,* 2010). Tomato fruits have a short shelf life, ripes within 5-7 days at 20-25^{0}C and become overripe and gets spoilt within 15 days after harvesting (Desneux *et al*., 2010).

The pests reported to infest tomato across the world are corn earworm *Helicoverpa zea* (Boddie) (Lepidoptera: Noctuidae), tobacco hornworm *Manduca quinquemaculata* (Haworth) (Lepidoptera: Sphingidae), and Yellow-striped Armyworm *Spodoptera ornithogalli* (Guence) (Lepidoptera: Noctuidae). Others are green peach aphid *Myzus persicae* (Sulzer) (Hemiptera: Aphididae), *red spider mite Tetranychus urticae* (Koch) (Acari: Tetranichidae), potato leafhopper *Empoasca fabae* (Harris) (Hemiptera: Cicadellidae) and tomato leaf miner moth *Tuta absoluta* (Meyrick) (Lepidoptera: Gelichidae) (Varela *et al*., 2003; Jaworski *et al*., 2015).

In Kenya, some of the pests that affect tomatoes are blossom thrips *Frankniella schultzei* (Trybom) (Thysanoptera: Thripidae), *cabbage looper Trichoplusia ni* (Hubner) *(*Lepidoptera: Noctuidae*)*, and vegetable leaf miner (*Liriomyza sativae* (Blanchard) (Diptera: Agromyzidae) (Larsen, 2009). In addition, the beet armyworm *Spodoptera exigua* (Hubner) has also been reported to attack tomatoes (Lepidoptera: Noctuidae) (Larsen, 2009).

Currently, the most damaging pest affecting tomatoes is *T. absoluta* (Desneux *et al*., 2010). The pest is native to South America and was first reported in Spain in 2006; since then, it has spread to the Mediterranean Basin and Europe (Desneux *et al*., 2010). The pest is also found in Asia and in Africa and has colonized the whole of Sub Saharan Africa within less than three years of its first report. Recent identification of *T. absoluta* in Niger, Senegal, Sudan and Ethiopia will seriously affect tomato production in the whole of Africa (Pfeiffer *et al*., 2008).

This pest can attack tomato plants at any developmental stage by mining the leaves, boring stems and fruits by its larvae negatively affecting the crop yield and fruit quality (Ferracini *et al*., 2012). It can cause yield loss of up to 100% if control strategies are not taken immediately after detection (Hart, 2013). Most farmers have adopted insecticide spraying to control the pest. However, due to endophytic behaviour of the larvae, and rapid evolution of resistance in the field, this method has not been successful (Lietti *et al*., 2005). Most farmers use synthetic insecticides for the control of tomato pests which pose dangers resulting to pest resistance to pesticides, environmental degradation, pollution, pest resurgence and residual effects on the crop (Guedes and Picanço, 2012). Inappropriate use of chemicals has increased the cost of production and has negative effects on food safety (residues) as well as decimated beneficial arthropods (Desneux *et al.,* 2010).

Based on the economic importance of tomato, its nutritive value and its potential of alleviating poverty in Kenya, there is a need to protect the crop from pests that limit its production. In Kenya, the population growth of *T. absoluta* is currently unknown, which is essential in knowing the population build-up of the pest in relation to the damage levels that it causes to the crop. The objective of this research was to assess the population growth of *T. absoluta* and its relationship to yield loss.

2.0 Tomato production in Kenya

In Kenya, tomato is one of the promising horticultural crop with promising and expansion development in the country as it contributes to 20% of the total vegetable production and 6.70% of the horticultural crops (HCDA, 2016). Kenya is ranked sixth in terms of tomato production in Africa with the three leading counties being Kajiado, Narok, and Kirinyaga, (HCDA, 2017). In 2017, the area, volume and values of tomato production in Kenya went up by 21%, 49%, and 11% respectively. This can be attributed to the use of greenhouses, expansion of irrigation, high enterprise returns and recovery from the 2016 drought. Additionally, more farmers are also adopting the use of hybrid varieties as opposed to the conventional ones.

The tomato harvested in the country is marketed within and East Africa. Most of the tomato production in Kenya is on the open field and this greatly affects the supply of fruits during the off seasons and season glut. Use of greenhouse is currently on the increase through the promotion of stakeholders such as HCDA and the Ministry of Agriculture hence ensuring that there is a constant supply of fruits in the market throughout the year. The ministry of agriculture is focusing on the use of greenhouse to increase production in the rural areas, to create employment and as a way of improving food security in the country (HCDA, 2016).

2.1 Origin of *Tuta absoluta*

Tomato leaf miner moth *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae) is native to South America and is currently a threat to production of tomato in the Mediterranean Basin and is becoming a serious pest in most African countries (Desneux *et al.,* 2010). *Tuta absoluta* was first observed in Eastern Spain in 2006 and two years later in North Africa. Since then, the pest has spread throughout Southern Europe, North Africa and Middle East. It is important to come up with strategies that can help in controlling the pest population.

Currently, *Tuta absoluta* is the most damaging pest of tomatoes, both in open fields and greenhouses in South America where it originated and Spain where it was identified in 2006 (IRAC, 2014). The pest can cause yield loss of up to 100% if not managed; it is estimated that about 87.4% of tomato production is threatened by the pest worldwide (Desneux *et al.,* 2011). The larvae mine the leaves and burrow into fruits causing huge losses to tomatoes (Salvo and Valladares, 2007).

The spread of *T. absoluta* across the Mediterranean basin has been primarily by importation of fruits; the pest can also fly a few kilometers and can be carried away by the wind (Van Deventer, 2009). In Africa, the pest was identified first in Tunisia in 2008 (EPPO, 2008). Other countries where the pest has been identified in Africa include Ethiopia, Niger, Sudan and Senegal. In Kenya, the pest was identified for the first time in Mpeketoni in March 2014 during a joint survey carried out by International Centre of Insect Physiology (ICIPE) and Kenya Plant Health Inspectorate Services (KEPHIS) (IPPC, 2014). Currently, it has spread across the country including Nairobi, Kirinyaga, Njoro, Meru, Loitokitok, Kakamega and Lamu (IPPC, 2014). The neighboring countries such as Uganda, Tanzania, and Sudan have also been affected by the invasive pest (Tonnang *et al*., 2015). In Kenya, the pest was identified for the first time in Mpeketoni in March 2014 during a joint survey carried out by International Centre of Insect Physiology (ICIPE) and Kenya Plant Health Inspectorate Services (KEPHIS) (IPPC, 2014). Currently, it has spread across the country including Nairobi, Kirinyaga, Njoro, Meru, Loitokitok, Kakamega and Lamu (IPPC, 2014). The neighbouring countries such as Uganda, Tanzania, and Sudan have also been affected by the invasive pest (Tonnang *et al*., 2015).

2.2 Host Crops of *Tuta absoluta*

Tuta absoluta mainly attacks tomato. However, there are alternative host crops such as potato *S. tuberosum* (L), wild tomato *S. Habrochaites* Thunberg, *S. Lyratum,* (Thunb) and melon shrub *S. Muricatum* (Ait). In some instance, the pest has been found to infest tree tobacco *Nicotiana glauca* (var), eggplant *S. melongena* (L) (Aubergine), fumo petume *Nicotiana tabacum* (L) and chilli pepper *Capsicum annum* (Bawin *et al*., 2016). In addition, there are wild hosts that it can feed on such as black night shade *S. nigrum* (L), silver leaf nightshade *S. elaeagnifolium* (var), glowing nightshade *S. pseudogracile* (Heiser), Jerusalem cherry *S. pseudocapsicum* (L). Other crops include green nightshade *S. viride* (G), sticky nightshade *S. sisymbriifolium* (Lam), Indian nightshade

S. aculeatissimum (Jacq), American nightshade *S. americanum* (Mill), thorn apple *Datura stramonium* (L) (Portakaldali *et al*., 2013).

2.3 The economic impact of *Tuta absoluta* on tomato

Tuta absoluta arrived in Europe in 2006 and it has continued to spread rapidly through Europe and the Mediterranean regions where it is a serious pest of both field and greenhouse grown tomatoes (Barrientos *et al*.,1998; Estay, 2000). Both yield and quality of fruit can significantly be reduced by the larvae by directly feeding on the fruit thereby allowing secondary pathogens to enter the mines that may cause the fruit to rot. Severely attacked fruits lose their commercial value. Damage to the terminal buds negatively affects the plant architecture that may result into reduced plant growth and decreased fruit yield (NAPPO, 2010).

3.0 Research Methodology

3.1 Study Area: This study was carried out in Loitokitok district Kajiado County, Kenya between June 2015 to October 2015. The area is located at 2° 55' 30.00"S, 37° 30' 36.00"E. The rainfall amount and reliability vary according to the agro ecological zone ranging from 450 mm to 1250 mm. The area experience two key rainfall seasons light rains between March to May and heavy rains between October to December. The rainfall pattern is not distributed equally due to the existence of Mt Kilimanjaro that causes the lowest altitude to receive about 500mm while the mountain slops receives an average of 1250 mm. The temperature also varies as a result of varying altitude from 10°C to mean maximum temperature of 30°C. Trial site was at Entarara, Loitokitok district with the experimental plot measuring 13.5 m x 10.5 m.

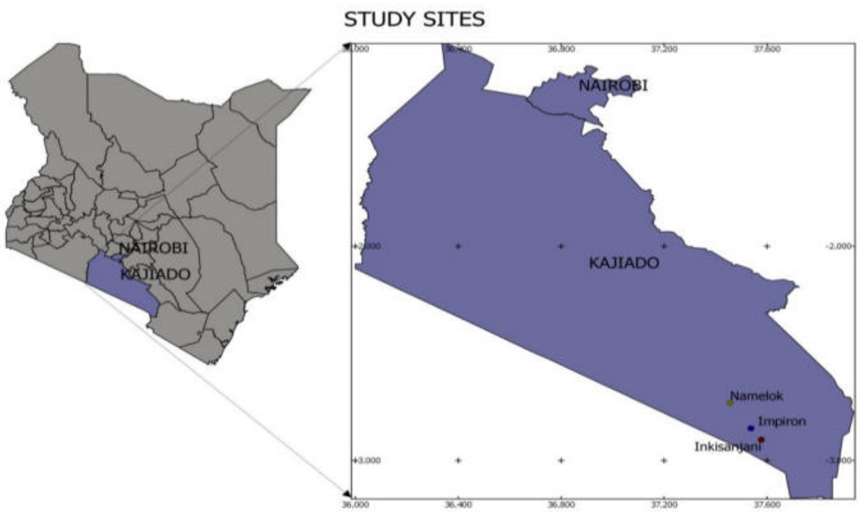

Figure 1: Geographical Location of the study area in Loitokitok

3.2 Research design and methodology

The study was conducted in a split plot arrangement in Randomized Complete Block Design (RCBD) with two factors (2 Varieties x 2 Control) replicated 3 times per treatment. Two varieties of tomato Kilele and Rio grande constituted the main plot and pesticide constituted the sub plot. Chlorantraniliprole was used as a treatment factor which was applied on 6 plots (3 Kilele F1 and 3 Rio grande varieties) and the rest was not sprayed to act as a control. There were 12 sub plots each measuring 3 m long and 3 m width with spacing of 0.3 m along the beds and 0.3 m across the beds. The tomato seeds were first sown in the nursery and transplanted four weeks at spacing of 60 cm between the rows and 60 cm within rows. Di-ammonium phosphate (DAP) was applied at the rate of 10g per hole at transplanting. Weeding was done after four weeks in both sites. Calcium ammonium nitrate (CAN) was applied after weeding at the rate of 10 g per plant.

3.3 Data collection

Determination of *T. absoluta* larval population was done weekly starting three weeks after transplanting until harvesting. Ten plants were randomly sampled from each experimental bed during which pest larvae was collected from the plants affected. Destructive sampling was used which involved plucking of infested leaves that had larvae by direct inspection of plants. Sampling was done weekly during the entire cultivation period with each sub-plot consisting of 25 inspected leaves. The number of pest larvae were counted and recorded on a data sheet. The larvae were then placed in a container lunch box lined with muslin cloth to absorb the moisture. Data on part of the plant affected, and the number of larvae were recorded from which population of the pest was determined. To determine the infestation levels of tomato fruits, the number of total damaged fruits was counted from the total harvested fruits from each plot and weighed for each of the treatment factors weekly using a weighing scale. Harvesting was done weekly for four weeks. The infested fruits were characterized by a small hole near the calyxes.

3.4 Data analysis

Descriptive statistics was used to analyze data from the survey based on percentage occurrences reported by the respondents. The Statistical Package for Social Sciences (SPSS) version 20.0 was used in analyzing the data on survey. Data on larval population from both locations were subjected to Analysis of Variance (ANOVA) using SAS- computer software (SAS 9.0). Where significant difference occurred, the means were separated using LSD. The level of significance was set at P<0.05. Yield losses, due to different treatments were calculated by deducting the total fruits tunneled from the total harvested fruits multiplied by 100 in order to get the percentage (Pedigo, 2006).

4.0 Results and discussion

4.1 Population growth of *Tuta absoluta* recorded on tomato plants

The total mean number of larvae collected weekly during the period ranged from 1.3±0.6 to 20.8±3.4 in the protected plants and from 4.3±0.6 to 51.7±2.1 in the unprotected plants. There was no significant difference between the protected and unprotected plants in week 1 ($F_{1,1}$ = 5.08; p = 0.07). Kilele and Rio grande did not show significant difference in regard to pest preference except in week 5 that had a significant difference ($F_{1,1}$ = 6.56; p = 0.05) (Table 1).

Table 1: The mean numbers (±S. E) of *T. absoluta* infestation on tomato plants in Loitokitok.

Weeks	3	4	5	6	7	8	9	10
Treatments								
Protected Plants	2.3±0.6a	1.3±0.6a	4.0±0.9a	15.5±0.7a	1.8±0.7a	16.3±4.1a	26.5±2.7a	20.8±3.4a
Unprotected	4.3±0.6a	6.8±0.7b	10.1±0.9b	25.3±1.8b	30.7±1.7b	42.7±4.0b	39.8±1.2b	51.7±2.1b
$F_{1,1}$-value	**5.08**	**41.35**	**41.03**	**77.88**	**115.81**	**17.00**	**30.33**	**78.20**
***p*-value**	**0.07**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**
LSD	**2.2**	**2.1**	**2.6**	**4.2**	**5.3**	**15.6**	**5.9**	**8.5**
Varieties								
Kilele	3.8±0.7a	3.8±1.0a	6.0±1.4a	22.3±3.1a	14.7±5.6a	29.5±5.6a	32.3±4.1a	33.5±7.7a
Rio Grande	2.8±0.7a	4.3±1.7a	8.7±1.9b	23.8±4.1a	12.5±5.1a	29.5±8.4a	34.0±3.1a	39.0±6.9a
$F_{1,1}$-value	**1.27**	**0.34**	**6.56**	**0.76**	**0.98**	**0.00**	**0.47**	**2.49**
***p*-value**	**0.30**	**0.58**	**0.05**	**0.42**	**0.36**	**1.00**	**0.52**	**0.12**
LSD	**2.2**	**2.1**	**2.6**	**4.2**	**5.3**	**15.6**	**5.9**	**8.5**

Means followed by the same letter within the same column are not significantly different (P≤0.05)

4.2 Effect of treatment on the number of tomato yield harvested from Loitokitok

The mean number of marketable fruits was higher for the protected than the unprotected tomato crops. The number of marketable fruits were significantly higher in the protected plots (68.4±7.8) compared to the unprotected plots (42.5±5.6) in the fourth week of harvest ($F_{1,1}$ = 7.89; p = 0.03) (Table 2). There was significant difference on the mean number of infested tomato fruits that were collected from the protected compared to the unprotected plots in week 2 ($F_{1,1}$ = 11.06; p = 0.01), week 3 ($F_{1,1}$ = 8.20; p = 0.03) and week 4 ($F_{1,1}$ = 6.04; p = 0.05) (Table 2). However, no significant difference was realized on the mean number of infested fruits that were collected in week 1 ($F_{1,1}$ = 2.77; p = 0.15) from the protected and unprotected plants. Kilele variety was significantly infected more than Rio grande variety in week 1 ($F_{1,1}$ = 24.96; p = 0.003). Significant difference ($F_{1,1}$ = 14.72; p = 0.01) was also noted in week 2 between the mean number of tomato fruits collected from Kilele which was higher than Rio grande. No significant difference ($F_{1,1}$ = 3.31; p = 0.11) was noted in week 3 on the mean number of infested fruits collected from Kilele and Rio grande. There was also no significant difference ($F_{1,1}$ = 1.93; p = 0.21) noted in week 4 on the mean number of infested fruits on Kilele and Rio grande (Table 2). The mean number of marketable fruits for Kilele and Rio grande showed significant difference ($F_{1,1}$ = 33.07; p = 0.001) in week 1. However, no significant difference was noted in week 2 ($F_{1,1}$ = 4.74; p = 0.07), week 3 ($F_{1,1}$ = 0.16; p = 0.70), and 4 ($F_{1,1}$ = 0.00; p = 0.98) (Table 2).

Table 2: The mean numbers (+S. E) of marketable and unmarketable yield harvested from Loitokitok.

	Number of marketable fruits				Number of unmarketable fruits			
Weeks	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
Treatments								
Protected plants	13.9+2.6a	38.4+7.9a	53.2+8.2a	68.4+7.8a	5.2+1.4a	16.2+4.4a	27.0+4.9a	40.8+5.5a
Unprotected	9.2+2.2b	23.7+2.2b	29.2+4.2b	42.5+5.6b	6.3+0.6a	29.2+4.9b	44.7+5.4b	60.0+5.5b
***$F_{1,1}$*-value**	**17.95**	**5.74**	**6.91**	**7.89**	**2.77**	**11.06**	**8.20**	**6.04**
***p*-value**	**0.001**	**0.05**	**0.04**	**0.03**	**0.15**	**0.01**	**0.03**	**0.05**
LSD	**2.7**	**14.9**	**22.3**	**22.5**	**1.7**	**9.6**	**15.1**	**19.1**
Variety								
Kilele	14.7+2.5a	37.7+8.1a	43.0+10.1a	55.5+10.8a	7.5+0.7a	30.2+3.9a	41.5+4.9a	55.8+6.1a
Rio grande	8.4+1.8b	24.4+2.4a	39.3+5.3a	55.3+6.4a	4.0+0.8b	15.2+4.7b	30.2+6.9a	45.0+6.9b
***$F_{1,1}$*-value**	**33.07**	**4.74**	**0.16**	**0.00**	**24.96**	**14.72**	**3.37**	**1.93**
***p*-value**	**0.001**	**0.07**	**0.70**	**0.98**	**0.01**	**0.01**	**0.11**	**0.21**
LSD	**2.7**	**14.9**	**22.3**	**22.5**	**1.7**	**9.6**	**15.1**	**19.1**

Means followed by the same letter within the same column are not significantly different (P≤0.05)

4.3 Effect of treatments on weight of marketable and unmarketable tomato yield

The mean weight of marketable tomato fruits collected from the protected plants were higher than the unprotected tomato plants from week 1 to week 4. There was a significant difference ($F_{1,1}$ = 8.37; p = 0.03) between the mean weight yield of the protected plants which registered higher mean weight yield in week 4 compared to unprotected plants (Table 3). Significant difference ($F_{1,1}$ = 18.75; p = 0.005) was noted on the mean weight of marketable yield on Kilele which was higher than Rio grande in week 1. There was also significant difference ($F_{1,1}$ = 6.3; p = 0.05) on the mean weight of marketable tomato fruits that were collected from Kilele which was higher than Rio grande in week 2. However, no significant difference was registered between the two varieties in week 3 ($F_{1,1}$ = 0.16; p = 0.7) and 4 ($F_{1,1}$ = 0.01; p = 0.9) (Table 3).

There was no significant difference ($F_{1,1}$ = 1.67; p = 0.24) registered on the mean weight of unmarketable tomato fruits collected from the protected (0.5±0.1) and unprotected plants (0.6±0.1) in week 1. However, significant difference was registered in week 2 ($F_{1,1}$ = 10.65; p = 0.02), week 3 ($F_{1,1}$ = 0.03; p = 7.73) and week 4 ($F_{1,1}$ = 6.61; p = 0.04) (Table 3). In regards to tomato varieties, there was significant difference on the mean weight of unmarketable fruit yield that was collected in week 1 ($F_{1,1}$ = 24.07; p = 0.002) for both Kilele and Rio grande. There was also a significant difference in week 2 ($F_{1,1}$ = 16.43; p = 0.007) on the mean weight of fruits collected from Kilele and Rio grande. However, mean weight of unmarketable fruits collected from Kilele and Rio grande in week 3 did not show a significant difference ($F_{1,1}$ = 3.98; p = 0.09). No significant difference ($F_{1,1}$ = 2.41; p = 0.17) was also realized from the mean weight of unmarketable Kilele and Rio grande variety in week 4 (Table 3).

Table 3: The mean weight (+S. E) of marketable and unmarketable tomato fruits

	Number of marketable fruits				Number of unmarketable fruits			
Weeks	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
Treatments								
Protected plants	1.3±0.2a	3.7±0.8a	5.1±0.8a	7.1±0.8a	0.5±0.1a	1.6±0.4a	2.6±0.5a	4.2±0.6a
Unprotected	0.9±0.2b	2.3±0.2b	2.7±0.4b	4.3±0.6b	0.6±0.1a	2.8±0.5b	4.3±0.5b	6.2±0.6b
***$F_{1,1}$*-value**	**6.29**	**6.0**	**7.32**	**8.37**	**1.67**	**10.65**	**7.73**	**6.61**
***p*-value**	**0.05**	**0.05**	**0.04**	**0.03**	**0.24**	**0.02**	**0.03**	**0.04**
Variety								
Kilele	1.4±0.2a	3.7±0.8a	4.1±1.1a	5.7±1.1a	0.7±0.1a	3.0±0.3a	4.0±0.5a	5.8±0.6a
Rio grande	0.8±0.2b	2.3±0.2b	3.7±0.5a	5.6±0.7a	0.4±0.1b	1.4±0.5b	2.8±0.7a	4.6±0.7a
***$F_{1,1}$*-value**	**18.75**	**6.3**	**0.16**	**0.01**	**24.07**	**16.43**	**3.98**	**2.41**
***p*-value**	**0.01**	**0.05**	**0.7**	**0.9**	**0.01**	**0.01**	**0.09**	**0.17**

5.0 Discussion

Loitokitok registered high number of larval populations of *Tuta absoluta* due to the favorable environmental conditions within the area and presence of alternative hosts that can allow the pest to complete its life cycle when tomatoes are not in season. da Silva Krechemer and Foerster (2015) reported that temperature has a significant effect on larval survival rates of *T. absoluta* which is 80.8% at 25±2ºC. Warm climatic conditions allow for faster development of the pest population and improved metabolic rate (Roy *et al*., 2002; Bueno *et al*., 2013). *T. absoluta* is a multivoltine pest making its generation to be noted in the field always. In Loitokitok for instance, there are other crops such as eggplant and potatoes which acts as alternative host when tomatoes are not in season. Moreover, the area has a number of non Solanacious species which also act as hosts, among which is the common bean (Desneux *et al*., 2010). In KU, the temperatures were low during the season leading to reduction of the metabolic rate and slower development of the pest (Roy *et al*., 2002). The choice of tomato varieties used in the experiment was based on market demand. Results showed no significant difference on pest preference to tomato variety.

Use of pesticide in this study was to protect the plants from being attacked by the pest. The larval population observed from the sprayed crops might have been attributed by the mine feeding behavior of the larvae which allows it to escape insecticide sprays and this also shows how difficult it is to control the pest (Lietti *et al*., 2005). Illakwahhi *et al*. (2017) also reported that control of the pest using chemicals has challenges due to the mine feeding method by the larvae within the plant tissues hence protecting them from coming to contact with the insecticides. This could have been the main reason why crops that were protected also had larval populations. The pesticide only works when it comes into contact with the pest, but when they feed within the plant tissue, they are protected from coming into contact with the pesticide hence reducing the performance of the chemical.

In Loitokitok, low number of larval population was recorded a week after every application of Chlorantraniliprole. The larval population would then increase systematically before the next insecticide application. According to DuPont™ (2008), use of Chlorantraniliprole causes *T. absoluta* females to oviposit significantly fewer eggs. Mahmoud *et al.* (2014) reported a reduction in infestation of *T. absoluta* a day after treatment of plants with Chlorantraniliprole, the infestation would then increase systematically within 2 weeks of treatment.

Mahmoud *et al.* (2014) also reported a reduction (95%) on the number of eggs laid by *T. absoluta* one day after spraying plants, which would then increase three weeks later. The pest has high reproductive potential to the extent that they can have 10 to 12 generations per year under favorable conditions (Illakwahhi *et al*., 2017). He asserts that, with such high reproductive potential, they are capable of undergoing genetic changes hence resulting to pesticide resistance.

The development of the pest in fruits was easy due to the warm climatic condition in the area that favors its development. This result is in agreement with the study done by Tonnang *et al.* (2015) who recorded that the occurrence of *T. absoluta* in warm areas is an indication that the pest is heat tolerant. High damage to tomato fruits could also be attributed to the fact that the pest had already established in the area. Tonnang *et al*. (2015) reported that increase in population of *T. absoluta* result in high yield losses in areas where the pest has established.

Conclusion

T. absoluta damages on tomato occur throughout the phonological stages of the crop hence successful control strategies should target all the stages of the crop. Management of *T. absoluta* should be put in place throughout the growing season of tomato and critically during the period when there is an influx of tomato production.

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